

LIMITED CIRCULATION

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A technique that has been used in an attempt to map Median Maximum Potential Soil Moisture Deficit

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1. Introduction

The reasons for the interest in mapping Median Maximum Potential Soil Moisture Deficit (MMPSMD) for Agricultural Land Classification can be found in references (1), (2), (3) and (4). The requirement is to map MMPSMD on a scale of 1:625000 for England and Wales. The maximum value of Potential Soil Moisture Deficit is found each year over the period 1961-80; the median value is calculated from the 20 annual maxima. This is the parameter that is mapped.

2. Background to the Problem

The technique described in this paper has actually been used to produce a map of MMPSMD. However there are serious problems with the map because the limited network of meteorological stations gives rise to a field of Potential Evapotranspiration (PE) which does not appear to be smooth and well-behaved but is very 'noisy' - this is described more fully in (5). This leads to inconsistencies in the field of MMPSMD which render the map unsuitable for statutory purposes. These inconsistencies can be illustrated by means of the following example.

Parts of the Lincoln Wolds and the Yorkshire Wolds have an Average Annual Rainfall of 700 mm and are at approximately the same altitude of 60 m. Their physical separation is about 50 miles. Thus one would not expect there to be large differences in their MMPSMD's. However because the PE data for the two areas are not taken from the same meteorological station but from two different stations, whose estimates of PE are significantly different, quite large differences in MMPSMD result, see Table 2.1.

Table 2.1

Location	Altitude (m)	AAR (mm)	MMPSMD (mm)	Nearest Met. Station	Estimate of Ave. Annual PE at 60 m (in mm)
Lincoln Wolds	60 }	700 }	96	Skegness	472
Yorkshire Wolds	60 }	700 }	131	Hull	586

In many other parts of the country inconsistencies such as this can be found. Many attempts have been made by the author to obtain a smoother field of PE by 'rationalizing' the network of sites, e.g. by removing those stations that appear to give rather high or low estimates of PE. These

attempts have failed because (i) there is still a great deal of residual 'noise' in the PE field and (ii) the number of remaining sites becomes too small to work with.

3. Technique for producing the map of MMPSMD

Since MMPSMD is derived from the cumulative difference between PE and rainfall (RF), to map MMPSMD the first requirement is to obtain information on the spatial variability of both PE and RF.

The most accurate and up-to-date climatological information on the spatial variability of rainfall in England and Wales is contained in the 1941-70 AAR map of Britain (6). The most up-to-date climatological information on the spatial variability of PE consists of estimates made at each of the 94 stations on the 'Complete' Agromet Dataset (7). Thus the technique to map MMPSMD needs to combine spot values of PE and rainfall from the 94 sites with the smooth pattern of rainfall from the AAR map.

To find MMPSMD at each of the 94 meteorological stations is a simple task. It involves running a program for each station in turn that calculates the daily PSMD over the 20-year period and then finds the median max value (see Appendix I). However some means needs to be found of calculating MMPSMD at an arbitrary point and not at the station itself.

Consider a remote site which has the same daily PE as the meteorological station but which has an Average Annual Rainfall of AAR_i; the AAR at the meteorological station is AAR_s. The value of MMPSMD at the site can be estimated by re-running the program for the meteorological station and replacing its daily rainfall RFs by RF_i where,

$$RF_i = RF_s \cdot AAR_i / AAR_s \quad 3.1$$

In general the site will not have the same daily PE as the station. In particular if AAR_i > AAR_s then the site will almost certainly be at a greater altitude and hence have a lower PE. Monthly PE can be related to altitude in a simple fashion, see Table 3.1

Table 3.1 Decrease of Monthly PE with altitude (see (9))

	mm per 100 m		mm per 100 m
Apr	3.5	Jan	1.5
May	3.5	Feb	2.0
Jun	3.0	Mar	3.0
Jul	3.0	Oct	1.5
Aug	2.5	Nov	1.0
Sep	2.0	Dec	1.0

Thus if the difference in altitude Δalt between the site and the meteorological station can be estimated then the daily PE at the site, PE_i, can be found from the PE at the station, PE_s, as follows

$$PE_i = PE_s - MF \cdot \Delta alt / (100 \cdot NDIM) \quad 3.2$$

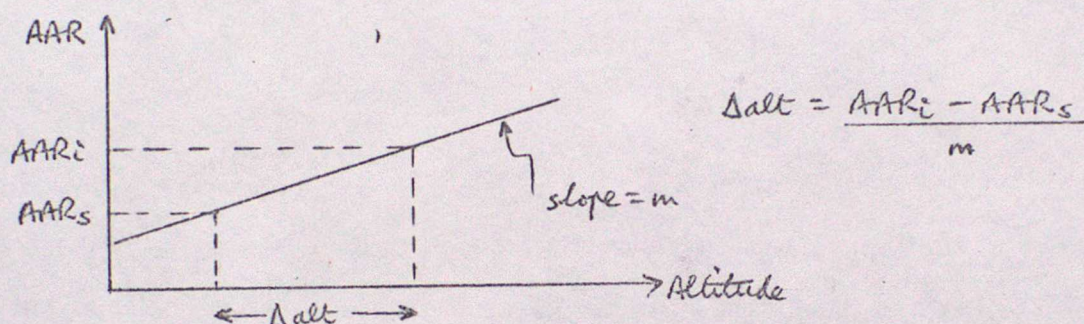
where MF = Monthly Factor (in mm per 100 m)
and NDIM = Number of Days in the Month

PE_s is found for a grass surface using MORECS algorithms (10).

If a simple relationship between AAR and altitude can be found then Δalt can be inferred from AARs and AARi. The advantage of this is that detailed information on Average Annual Rainfall is readily available from the AAR map (6) so that reference to a separate map of altitude (a Relief Map) is avoided. The altitude correction to PE does not need to be found very accurately because the rainfall pattern dominates the field of MMPSMD in areas of changing relief. To this end England and Wales were divided into regions in which the AAR vs altitude curve was approximately a straight line (8); there were 11 regions in all. The number of regions could have been increased and by so doing the scatter on the rainfall vs altitude diagrams would have been reduced. However this would have increased the complexity of the task.

Δalt is related to AARs and AARi as follows

Fig 3.1



Thus substituting for Δalt in equation 3.2 we have

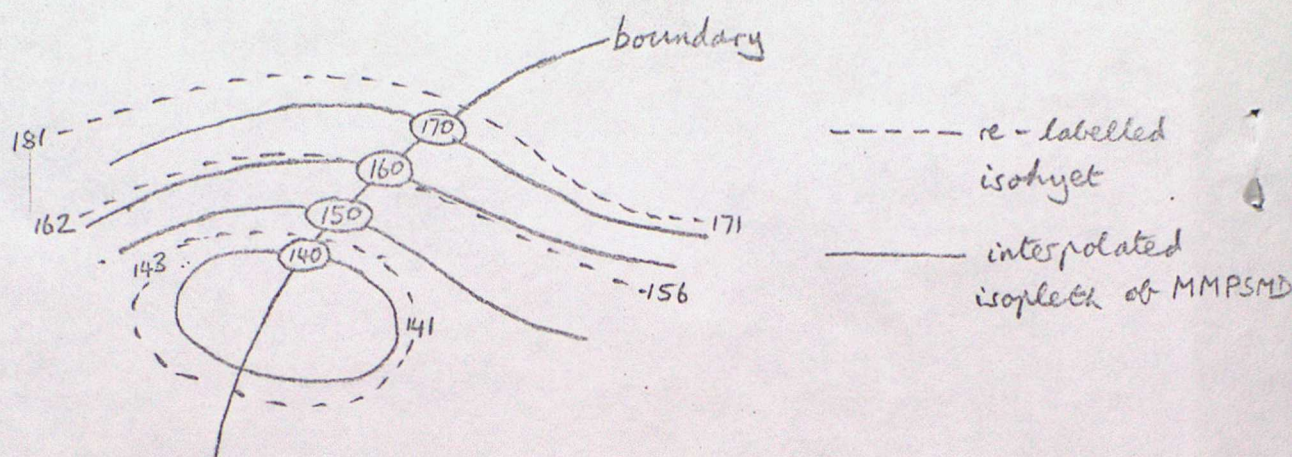
$$PE_i = PE_s - \frac{AAR_i - AAR_s}{m} \cdot \frac{MF}{100 \cdot N \cdot DIM} \quad 3.3$$

England and Wales were further subdivided into areas such that each area contained one meteorological station. The boundaries of these areas were made coincident with the boundaries of the 11 regions described above wherever possible (see Appendix II). Within each area the program to calculate MMPSMD was run n times where n is the number of isohyets in the area as identified on the AAR map. For each run the daily rainfall and PE at the meteorological station were replaced by estimates for the isohyet as given by equations 3.1 and 3.3 respectively. Thus the MMPSMD which was derived each time the program was run was the estimate for all sites along the isohyet. There is clearly an assumption here that all sites along the isohyet have the same altitude and hence the same daily PE. Some stations had only 1 or 2 isohyets in their area (e.g. Cardington - 550 and 600 mm) whereas others had several (e.g. Bude - 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 2000 and 2200 mm).

The values of the re-labelled isohyets were not in general continuous across boundaries because PE estimates from neighbouring stations were not equal. The largest discrepancies occurred at low altitudes in areas of

low rainfall where PE had greatest influence on PSMD. Isopleths of MMPSMD were interpolated between the re-labelled isohyets in such a way as to smooth-out the effect of the boundary, see Figure 3.2. These isopleths were drawn at 10 mm intervals of MMPSMD.

Fig 3.2



References

1. Agricultural Land Classification 1966, MAFF Technical Report No. 11.
2. Land Use Capability Classification, Bibby J.S. and Mackney D., 1969, Soil Survey Technical Monograph 1.
3. 'Agricultural Land Classification for England and Wales', MAFF, ADAS, December 1982 (unpublished report).
4. 'Land Capability Classification - a new approach? 1. Climatic Limitations', Douglas HA, Agricultural Memorandum No. 922, July 1981.
5. 'The Spatial Variability of Potential Evapotranspiration at Mean Sea Level in England and Wales and the implications for mapping Median values of Potential Soil Moisture Deficit', Field M, Agricultural Memorandum No. 997, October 1983.
6. Average Annual Rainfall (mm), 1941-70. Published by M.O., London Road, Bracknell, Met O 886 (scale 1:62500).
7. 'Creating the "Complete" Agromet Dataset', Field M, Agricultural Memorandum No., 983, July 1983.
8. 'The Relationship between Rainfall and Height', Agricultural Memorandum No. 976, Barrowcliffe R, May 1983.
9. 'The Agricultural Climate of England and Wales', MAFF Technical Bulletin 35 (1976). Table 9, page 11.

10. 'The Meteorological Office Rainfall and Evaporation Calculation System MORECS (July 1981)', Hydrological Memorandum No. 45, Thompson N, Barrie I A, Ayles M.

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APPENDIX I Station values of MMPSMD for the 94 stations held on the
'Complete Agromet Dataset'

Station	Grid Ref	Alt (m)	Average Annual PE (1961-1980)		AAR (1961- 1980)	Median Max PSMD (mm)	"m"
			Station Height	MSL			
Aberporth	SN 239 520	133	590	626	847	134	2.6
Askham Bryan	SE 552 475	34	538	547	614	147	1.5
Aylesbury	SP 842 114	96	505	532	615	131	1.0
Boscombe Down	SU 172 403	126	577	612	707	192	1.05
Braford	SE 149 352	134	560	597	874	125	1.5
Bramham	SE 431 412	54	500	515	652	129	1.5
Bude	SS 208 063	15	589	593	859	139	2.25
Buxton	SK 059 735	307	528	613	1280	82	1.7
Cambridge BG	TL 456 572	12	566	569	533	211	1.0
Cambridge NIAB	TL 434 604	26	579	586	538	227	1.0
Cardington	TL 081 464	29	546	554	541	189	1.0
Carlisle	NY 384 603	26	533	540	813	114	1.7
Cawood	SE 561 366	6	515	516	598	141	1.5
Cheltenham	SO 946 218	65	579	596	687	161	1.1
Cockle Park	NZ 200 912	99	490	517	724	103	1.5
Coltishall	TG 262 229	17	567	572	621	183	1.05
Cranwell	TF 003 494	62	534	551	580	168	1.0
Crumbland	SO 474 024	245	537	604	970	126	1.1
Cwmystwyth	SN 773 745	301	490	573	1720	49	2.6
Dalefort	SM 823 052	33	632	641	803	198	2.6
Durham	NZ 267 416	102	521	549	660	123	1.5
Eastbourne	TV 611 980	7	597	599	794	175	1.6
East Malling	TQ 708 570	37	542	552	646	183	1.05
Elmdon	SP 176 839	96	578	605	656	171	1.1
Everton	SZ 302 937	16	552	556	763	172	1.6
Faversham	TR 007 593	48	570	583	667	196	1.05
Fernhurst	SU 908 267	57	527	542	852	147	1.6
Filton	ST 600 805	59	606	622	764	175	2.25
Finningley	SK 659 989	10	580	583	578	190	1.05
Gatwick	TQ 265 407	59	514	530	760	139	1.6
Gloucester	SO 851 177	23	602	608	636	198	1.1
Gogerddan	SN 627 836	31	559	568	965	91	2.6
Gorleston	TG 534 037	4	585	586	571	206	1.05
Goudhurst	TQ 722 333	85	518	541	828	151	1.6
Hastings	TQ 809 094	45	566	579	730	175	1.6
Hawkrigde	SS 877 327	314	519	605	1425	82	2.25
Haydon Bridge	NY 838 646	79	538	560	708	136	1.5
Heathrow	TQ 077 767	25	619	626	603	233	1.05
Helmshore	SD 774 205	260	496	567	1473	63	1.7
H Mowthorpe	SE 888 685	175	516	565	752	122	1.5
Hoddesdon	TL 369 106	43	565	577	635	187	1.05
Hull	TA 084 302	2	602	603	658	184	1.5
Hurley	SU 823 829	43	560	571	679	162	1.05
Hurn	SZ 117 978	10	562	564	788	165	2.25
Keele	SJ 820 446	179	530	580	795	119	1.1

Station	Grid Ref	Alt (m)	Average Annual PE (.1961-1980)		AAR (1961- 1980)	Median Max PSMD (mm)	"m"
			Station Height	MSL			
Kew	TQ 171 757	6	622	624	574	232	1.05
Kirkham	SD 414 347	24	602	608	931	124	1.7
Leeming	SE 306 890	32	565	573	633	153	1.5
Loggerheads	SJ 201 622	210	527	585	930	110	1.7
L Ashton	ST 537 699	45	608	620	847	174	2.25
L Sutton	SU 748 467	145	520	560	788	150	1.05
Lowestoft	TM 543 947	25	561	568	581	199	1.05
Lyneham	SU 014 793	145	561	601	695	172	1.05
Lyonshall	SO 399 576	155	556	599	795	151	1.1
Manston	TR 335 666	44	609	620	579	252	1.05
Martyr Worthy	SU 517 338	84	528	551	778	152	1.6
M Batten	SX 492 529	27	602	610	982	151	2.25
Newport (Salop)	SJ 712 204	64	517	534	653	132	1.1
Newton Rigg	NY 493 310	171	519	566	891	111	1.7
Oxford	SP 509 072	63	582	599	642	184	1.05
Pen-y-Ffridd	SH 563 705	84	596	619	1109	96	2.6
Pershore Coll.	SO 959 449	40	591	602	629	187	1.1
Porton	SU 210 366	111	508	538	731	153	1.05
Preston Wynne	SO 565 475	84	521	545	651	141	1.1
Ringway	SJ 821 849	75	623	644	799	139	1.7
Rosewarne	SW 643 412	76	604	625	1114	114	2.25
Rothamsted	TL 132 134	128	523	558	682	155	1.0
Rustington	TQ 048 032	3	519	520	720	167	1.6
Rhooose	ST 064 679	67	595	614	904	133	2.6
Santon Downham	TL 813 901	24	525	531	633	142	1.05
Shawbury	SJ 553 221	72	531	551	657	147	1.1
Shoeburyness	TQ 948 857	2	615	616	508	249	1.0
Silpho Moor	SE 947 946	203	539	595	896	107	1.5
Silsoe	TL 092 358	61	540	557	535	174	1.0
Skegness	TF 569 631	5	487	489	592	131	1.05
Slaidburn	SD 717 547	192	527	580	1748	69	1.7
Stansted	TL 531 226	101	524	552	610	174	1.0
Starcross	SX 972 821	9	581	583	809	197	2.25
Stratford	SP 164 549	49	528	541	608	157	1.1
S Bonnington	SK 507 259	48	581	594	638	191	1.05
Swansea	SS 642 923	10	609	612	1152	103	2.6
Terr. St. Cl.	TF 547 187	3	517	518	574	151	1.0
Trawscoed	SN 674 736	61	560	577	1137	78	2.6
Valley	SH 310 758	10	627	630	843	165	2.6
Warsop	SK 591 699	46	527	540	624	155	1.05
Wattisham	TM 026 514	89	554	579	554	205	1.0
Wellesbourne	SP 271 565	47	542	555	585	161	2.6
Wisley	TQ 063 583	35	540	550	651	172	1.05
Wittering	TF 043 026	73	578	598	580	196	1.0
Woburn	SP 964 360	89	536	560	628	152	1.0
Writtle	TL 677 069	32	529	537	551	191	1.0
Wye	TR 057 469	56	537	552	731	166	1.05
Wyton	TL 283 745	40	589	600	533	216	1.0
Yeovilton	ST 551 237	18	579	584	762	144	2.25

